Vacant Lot Stabilization: Cleveland Best Practices

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Project Overview

With approximately 3,500 acres of vacant land, Cuyahoga County ranks third in the nation for highest land vacancy rate. Cleveland Botanical Garden (CBG) and The Ohio State University (OSU) jointly proposed testing a vacant lot stabilization protocol that was designed to address economic, ecological, and human health challenges posed by urban vacant land. Our protocol was based upon an urban greening initiative pioneered by Philadelphia and adopted by other cities, which aims to improve the aesthetic and economic value of vacant land through removing trash and debris, planting grass, and adding aesthetic components such as trees and fences (Philadelphia Green, 2002). Such "stabilization" of vacant land has been shown to increase property values of vacant and adjacent properties by as much as 30% (Wachter, 2004).

Based on several years of research conducted by CBG and OSU, we proposed the addition of ecological and human health considerations to the "cleaning and greening" stabilization model to further increase the economic benefits achieved by stabilizing vacant urban land. Specifically, we proposed:

(1) *Soil lead remediation to reduce human health risk posed by soil lead and restore soil organic matter/nutrients to degraded soils.* Lead contamination is pervasive in urban soils due to historic use of lead-based paints and gasoline. In Cleveland, a survey of soils from 50 public green spaces found lead contamination at a majority of sites, with 1 in 6 sites exceeding the residential safety threshold (Petersen et al., 2006). Further, contaminated runoff from urban areas is a primary source of metal deposition in the West Basin of Lake Erie and has been shown to redistribute throughout the lake (Ritson et al. 1994).

Phosphate soil amendments have been used for 20 years by the EPA and other institutions to bind to soil lead, making it irreversibly insoluble under natural conditions. Phosphate addition reduces lead toxicity by up to 85%; promotes soil microbial diversity; and reduces lead absorption by plants, fish, and animals. EPA-funded research promotes phosphate stabilization in urban soils that have moderate lead contamination. Although eutrophication of water sources due to phosphate contamination has been proposed as a concern, recent in-depth analyses have shown minimal phosphate water contamination after careful phosphate addition, while also demonstrating significant reductions in lead toxicity that justify its use (Yang et al. 2007).

(2) *The establishment of low-maintenance ("low-mow") lawns on vacant urban land to save money on vacant lot maintenance costs and reduce runoff quantity*. Low-maintenance lawns typically have deeper roots, slower-growing shoots, and higher species diversity than traditional lawns. Since 2007, CBG has been testing the performance of low-maintenance lawn mixes for use on vacant land in northeastern Ohio. Such lawns have the potential to significantly reduce maintenance costs associated with mowing and caring for vacant urban land, which amounts to $3.3 million in annual expenditures by Cleveland municipal government.

Assistance from the Lake Erie Protection Fund was used to test the safety and effectiveness of this enhanced "cleaning and greening" vacant land stabilization protocol at a 0.5-acre site in the Buckeye neighborhood in Cleveland. Preliminary soil testing found that approximately half

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of soil cores from the study location contained lead at or above the residential action level (400 ppm). Funds were primarily used to apply treatments and to measure soil quality under two different low-maintenance grass mixtures and under varying levels and forms of phosphate treatment. Our primary research questions were: Does our stabilization protocol reduce the portion of lead contained in soils that poses a risk to human health? How does stabilization increase water soluble phosphorus (P), which can be transported off-site by runoff? Does soil quality, including water soluble P, differ between two low-maintenance grass mixes? What are the estimated effects of lead and phosphorus runoff on the health of the Lake Erie watershed if this stabilization protocol were used on a larger scale within urban vacant areas?

Activities and Timeline

Site description

We secured access to two vacant residential lots in the Buckeye-Woodland neighborhood of Cleveland (parcels 121-33-123 and -128, hereafter referred to as East and West lots, 0.47 acres total; Figure 1). Based on county auditor records, these were formerly residential lots that had been demolished in 2008 and 2010. Both lots had been planted in a typical lawn seed mix following demolition and contained moderate amounts of weedy species typical to urban lots (e.g., chicory, wild carrot, clover), as well as small amounts of scattered trash and demolition debris. Preliminary soil tests conducted by a private contracting firm for Cleveland Botanical Garden indicated limited soil phosphorus (P), as well as soil lead (Pb) ranging from 90–1100 ppm across a 15-parcel area encompassing the site. The firm's recommendations to CBG included removal of the top 12 inches of soil or intensive soil remediation of lead contamination prior to site reuse.

Figure 1. Sites A and B prior to treatment. Sites are located in the Buckeye-Woodland neighborhood of Cleveland, bordered on the south by Woodland Avenue.

Soil remediation and runoff analysis

In early October 2010, we established 24 6-by-6-m study plots at the site, creating 6 lawn/soil treatment combinations (2 lawn treatments × 3 soil treatments) with 4 replicates each. Within each plot, we collected soil samples from 3 locations and combined these into 1 aggregate soil sample per plot. Samples were sent to OSU for detailed pre-treatment nutrient profiling and lead bioavailability assays.

We amended soil at the study site during October 5–12, 2010 (Figure 2). Existing vegetation was removed by careful application of glyphosate herbicide followed by mechanical scraping and raking of the soil surface. After vegetation removal, using a tractor and a hydraulic tiller, we spread 2.5 tons of poultry litter (3.2–2.5–3.0 N–P–K; Park Farms, Canton, OH) over the site and incorporated it to soil depths of 4–6 inches at a concentration of 5 tons/acre. Using a rear-tine rototiller, we additionally treated each 6-by-6-m plot with either soft rock phosphate (0-20-0) at 1.4 tons/acre, bone meal (4-12-0) at 2.4 tons/acre, or no additional phosphorus. Previous research has suggested that phosphorus remediation of soil lead occurs within 90 days of treatment; we collected post-treatment soil samples from plots in March 2011 using the same procedure as for pre-treatment sampling.

Our proposal had included the establishment of runoff plots to test for changes in the quantity and phosphorus content of runoff following remediation; however, hydrology experts from USDA-ARS and US EPA advised us that runoff plots were not as accurate as other methods over the short spatial and temporal scales used in our study. In consultation with William Shuster, Research Hydrologist at US EPA, in July 2011 we tested soil infiltrometry within 18 of 24 plots (3 replicates of each soil/lawn treatment combination) to test for relative differences in water infiltration among treatments. Additionally, we measured water soluble P in pre- and post-treatment soil samples to determine whether P addition to soils would likely contaminate runoff.

Figure 2. Left, incorporation of phosphate treatments into the soil. Right, removal of construction debris typical of most vacant lots,

Low-maintenance site beautification

Following soil remediation in October 2010, we seeded lots within our study site with one of two low-maintenance lawn mixes: a blend of microclover, fine fescue, and yarrow (PDX Ecology, Hobbs & Hobkins) or a mixture of several fine fescues (NoMow, Prairie Nursery). Both lawn mixes have been shown to perform well in low-maintenance installations in a variety of settings. We measured aerial cover of vegetation in each plot during summer 2011 to compare differences in vegetative establishment among treatment combinations.

During May–July 2011, a natural plant border was installed at the study site in a shallow, 4-m wide depression that had been dug at the time of soil treatment. The plant border was intended to visually define the area, much as the fences in Philadelphia Green's project had been shown to do, and also act as a swale to capture excess rainwater. A mixture of wood chips and compost (Ecomulch, Rosby Resource Recycling) was spread to depths of 6 inches across the border area. We planted each border with one of two plant species mixes compiled by horticulturists at Cleveland Botanical Garden. Plant mixes featured either easily sourced plants that are more common to landscaping (East lot) or predominantly native plants (West lot) and were designed to be low-maintenance, aesthetically appealing, and provide visual interest throughout the growing season (Table 1).

Table 1. Plant species mixes used at the Buckeye-Woodland stabilization site

West lot	East lot
Lawn seed mix: fescue/yarrow/microclover (PDX Ecology, Hobbs & Hopkins)	Lawn seed mix: fine fescues (NoMow, Prairie Nursery)
Plant border:	Plant border:
Molinia caerulea 'Skyracer'	*Rosa setigera*
Miscanthus sinensis 'Adagio'	*Panicum virgatum* 'Dallas Blues'
Pennisetum alopecuroides 'Moudry'	*Sporobolus heterolepsis*
Perovskia atriplicifoli	*Aster oblongifolius* 'Raydon's Favorite'
Lavatera thuringiaca 'Barnsley'	*Helianthus angustifolius* 'Gold Lace'
Rosa rugosa	*Amsonia hubrichtii*
Scabiosa columbari 'Butterfly blue'	*Sorghastrum nutans*
Deschampsia caespitosa 'Goldstaub'	*Calamagrostis* × *acutiflora* 'Eldorado'
Miscanthus sinensis 'Purperescens'	*Elymus arenarius* 'Blue Danube'

Dissemination of results

Preliminary results have been shared with the NSF-funded exploratory urban long-term research assessment (ULTRA-Ex). This collaborative of northeast Ohio scientists will be expanding our soil remediation methods and low-maintenance lawn recommendations to a 40-lot study of vacant lot stabilization in Cleveland. Scientists will measure a variety of ecosystem services provided by vacant land to determine the long-term effects of stabilization on plant and animal habitat, animal behavior, nutrient cycling, and water-/sewershed dynamics.

In early November, members of the Western Reserve Land Conservancy will conduct a site visit to discuss stabilization strategies in numerous northeast Ohio counties. We are also preparing a short scientific manuscript for publication in a technical journal.

Timeline

Timeline and activities as outlined in our proposal differed slightly from actual implementation; proposed and actual timelines are given in Table 2.

Results and Discussion

Soil remediation and runoff analysis

In-depth soil analysis revealed that most areas within our study site had lead levels below the EPA-recommended residential limit for bare soil in children's play areas (400 ppm Pb) prior to soil treatment (Table 3, Figure 3). Nonetheless, application of phosphate to soils at both sites reduced total lead content by 22% and 32% (Sites A and B, respectively, $P < 0.001$); reduced

Table 2. Comparison between project proposal and implementation for timeline and tasks

Proposed Timeline & Tasks	Actual Timeline & Modifications to Tasks
Phase I (June–Aug 2010):	
Testing of P compounds to identify type and quantity best suited for safe soil amendment.	Conducted prior to study.
Soil nutrient & Pb bioavailability testing.	Samples collected Phase I; tests completed Phase IV.
	Also completed: Secured site access, sourced materials, refined experimental protocol.
Phase II (Sept–Dec 2010):	
Site preparation.	Completed as described.
Application & incorporation of soil amendments.	Completed as described.
Runoff plot establishment.	Not completed. Instead, conducted soil infiltrometry and soil water-soluble P tests in Phase IV.
Seeding of groundcover mixes.	Completed as described.
Collection of 2 soil and water quality samples for analysis of phosphate content and lead bioavailability.	Soil samples only. Soil lab recommended testing only last post-treatment sample in exchange for more in-depth tests.
Landscaping, beautification.	Completed in Phase IV.
Phase III (Jan - Mar, 2011):	
Collection of 1 soil and water quality sample. Laboratory analysis of samples for phosphates & lead.	Only soil samples collected.
Phase IV (April - June, 2011):	
Quantitative and qualitative assessment of low-mow ground cover.	Completed as described.
Repeated measurement of soil lead bioavailability, soil nutrient studies, runoff quality and quantity assessment.	Not completed; additional testing not required.
Development of 2011 monitoring protocol.	Completed as described.
Strategic dissemination of vacant land management strategies.	In progress.

bioavailable (toxic) lead content by 31% and 51% ($P < 0.001$); and lowered the portion of bioavailable lead at each site by 9 and 12 percentage points ($P < 0.001$). After treatment, total soil lead averaged 42 ppm at site A and 195 ppm at site B. The three phosphate treatments were equally effective in reducing soil lead levels ($P \geq 0.438$ for differences among treatments).

At the same time, water soluble phosphorus—a form of phosphorus that is prone to runoff—averaged 12.05 ± 1.81 at Site A and 33.94 ± 8.34 at Site B after phosphorus addition (Table 3), which are within safe limits for residential lawns and pose little risk for runoff contamination. Other plant available nutrient deficiencies were corrected with soil treatment (data not shown) and treatment did not affect soil pH or salinity, which were within normal limits for soils underlying turf grass. Steady state infiltration of water was 1–4 mm per hour at both sites and did not differ among soil or grass treatments or between treated and untreated areas.

Together, these results suggest that our treatments reduced lead toxicity, improved soil quality, and had little impact on the quality or quantity of stormwater runoff at our sites.

Table 3. Effect of phosphorus treatment on soil total lead (Pb) and bioavailable lead (IVBA Pb)

		Total Pb (mg/kg)		IVBA Pb[3] (mg/kg)		% IVBA Pb[4]		Water soluble P (mg/kg)	
Site	**Treatment[1]**	**before[2]**	**after**	**before**	**after**	**before**	**after**	**before**	**after**
A	PL	49.3	41.7	30.3	21.1	60.9	50.9	3.40	17.1
	PL + RP	71.2	39.8	37.0	20.0	53.3	50.1	2.53	8.00
	PL + BM	40.7	44.9	25.7	22.5	59.6	49.5	2.89	11.0
	Site A Average	53.7	42.1	30.5	21.2	58.4	50.2	2.94	12.1
B	PL	368.4	279.1	219.8	133.1	60.4	50.9	29.8	21.2
	PL + RP	317.9	147.6	233.8	91.9	72.6	61.8	18.5	44.7
	PL + BM	259.3	156.5	179.1	85.9	69.5	56.3	23.3	35.9
	Site B Average	315.2	194.4	210.9	103.6	67.5	56.3	23.9	33.9

[1] Treatments are PL=poultry litter, RP = rock phosphate, and BM = bone meal
[2] before and after soil treatment
[3] IVBA Pb = in vitro bioaccessible lead
[4] %IVBA = (IVBA / Total Pb) x 100%

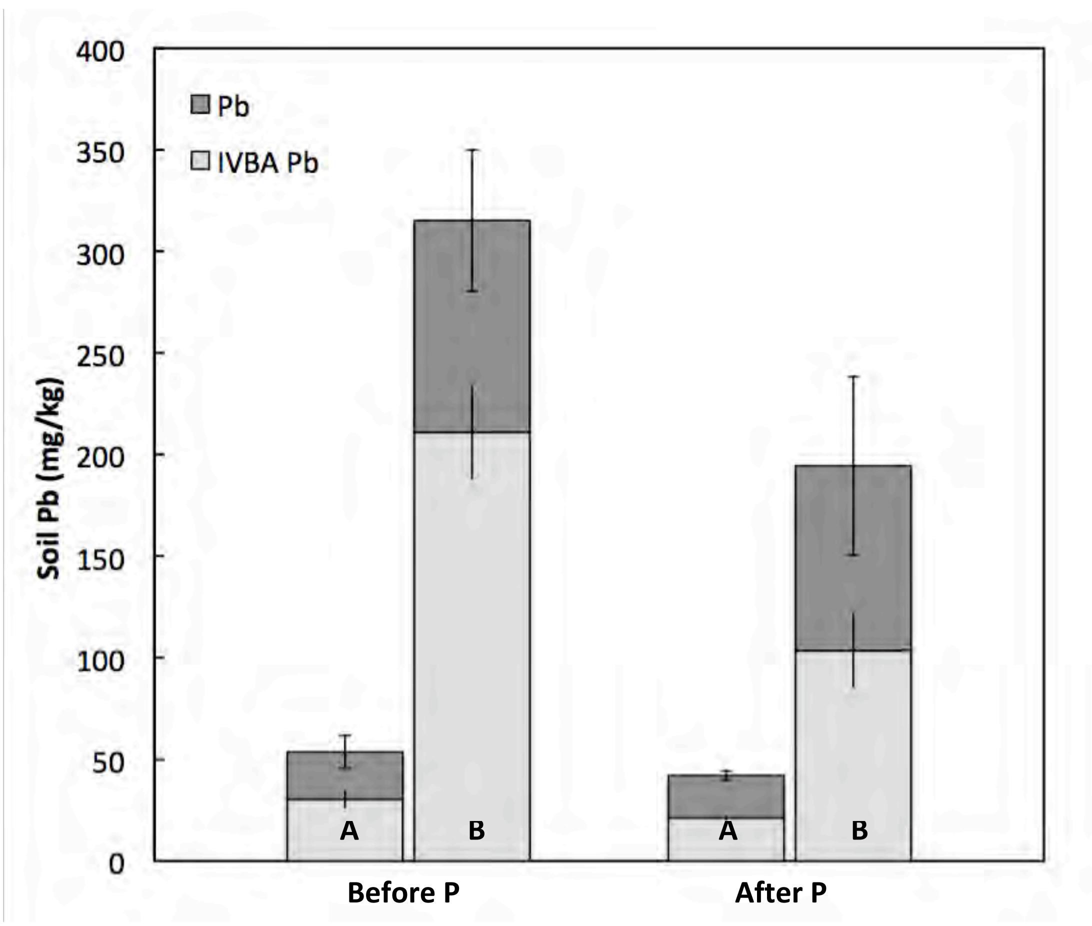

Figure 3. Total soil lead (Pb) and bioavailable lead (IVBA Pb) before and after phosphate treatment for Sites A and B.

Low-maintenance site beautification

During July, aerial cover of the PDX Ecology lawn mix averaged 75% across Site A, with aerial cover of other plant species (including weeds) less than 5% (Figure 4). At Site B, the NoMow mix averaged 50–75% aerial cover with other plant species covering an additional 25–50% (aerial cover can total more than 100% per lot if plants grow at different heights). Coverage of seed mixes were thicker in plots nearest the perennial plant border, possibly due to greater water availability at those locations.

At both sites, vegetative cover was compromised by human activity. Both sites were unexpectedly mown to heights < 2” by City maintenance workers during mid-July, the hottest and driest part of the summer, which likely killed lawn plants in some locations. At Site B, demolition of a building in an adjacent lot, as well as activity at the urban farm, trampled the lawn in several locations. This October, aerial cover of lawns at both sites were visibly less than they were in June, suggesting that they had been damaged. We will reevaluate lawn recovery early next spring and reseed the study site with PDX Ecology or NoMow mixes as indicated.

Plants for the site borders/bioswales became available in late June and were planted during the first week of July (Figures 5 and 6). Despite excessive heat and little rainfall, both plantings established successfully and only required one supplemental watering 3 days after planting. The wood chip/compost mixture retained water without becoming excessively wet, and we believe this helped the plants establish well under very low-maintenance conditions.

As slow-growing plants can take up to 3 years to become fully established, we will continue to monitor the growth of lawns and border plants over successive growing seasons.

Figure 4. First-season groundcover at Site A (grass-yarrow-clover blend) and Site B (fine fescues).

Figure 5. Below, Site B post-treatment. Inset, close-up of the plant border.

Conclusions and Recommendations

Our novel stabilization treatment shows promise for vacant urban land in Cleveland and other cities. Soil remediation is an important foundation of this treatment; it corrects nutrient deficiencies and reduces soil lead contamination. Over time, we believe this soil treatment will promote successful establishment of desirable plant species and discourage invasive weeds. We did not observe improvements to water infiltration within 1 year, but as the deeper roots of the low-maintenance lawn become established over the next 2 years, it is likely that water infiltration will increase, thereby reducing runoff.

The addition of phosphorus to our study site was performed carefully to prevent P-contaminated runoff, and caution should be used in repeating this treatment in other locations and/or over larger scales. We encourage preventative measures, like those taken in this study, to reduce the risk of runoff contamination: soil testing prior to treatment, titrating phosphate addition as indicated by test results, incorporating treatments into the first several inches of soil, seeding immediately following treatment, and the addition of swales to capture and filter runoff. Such preventative measures are necessary to ensure that phosphate addition is environmentally beneficial.

Although our stabilization treatment is designed to be low-maintenance once established, we also emphasize the importance of proper installation and management of low-maintenance plants during the first 1–3 years. Seeding these lawn mixes between mid-September and mid-October will help slower-growing lawn plants outcompete weeds and survive drought during the

Figure 6. Below, Site A post-treatment. Left, close-up of plant border.

initial growing season. Weed removal prior to installation, as well as mowing to 4” height during late spring and early fall during the first 1–3 years, will further promote establishment of lawn plants and discourage weeds. It may also be necessary to overseed lawns during the autumn following initial planting to encourage full coverage. Installation of low-maintenance lawns at other times of year, as well as lack of weed control during the establishment phase, will likely lead to failure of low-maintenance plant mixes. Thus, these seed mixes are best thought of as “regular-maintenance” for 1–3 years, but will require little to no mowing, fertilization, or watering in subsequent years.

The cost of our stabilization treatment can likely be reduced to ≤ $1200 per city lot by sourcing bulk materials and streamlining methodology. This cost would still be greater than what Cleveland currently pays for post-demolition treatments ($700–$1,000; personal communication, Cleveland City Planning Commission) but could be offset by lower maintenance expenses over time. It is also possible that a stabilization-induced increase in ecological services, such as water infiltration, could offset the cost of this treatment over time; quantification and monetization of ecological services provided by stabilized lots is an ongoing topic of research by Cleveland Botanical Garden and our collaborators in the NSF-funded ULTRA-Ex research group. Finally, an increase in neighborhood property values—by as much as 30%—in areas that have been intensively stabilized would further offset the additional cost of this treatment.

References

Petersen EJ, Jennings AA, and J. Ma. 2006. Screening level risk assessment of heavy metal contamination in Cleveland area commons. *Journal of Environmental Engineering*, 132: 392–404.

Philadelphia Green. 2002. Reclaiming vacant lots: a Philadelphia Green guide. Pennsylvania Horticultural Society, Philadelphia, PA. 86 pp.

Ritson PI, Esser BK, Niemeyer S, and AR Flegal. 1994. Lead isotopic determination of historical sources of lead to Lake Erie, North America. *Geochimica et Cosmochimica Acta*, 58:3297–3305.

Wachter S. 2004. The determinants of neighborhood transformations in Philadelphia - identification and analysis: The New Kensington pilot study. University of Pennsylvania, Philadelphia, PA. 24 pp.

Yang J, Campbell M, and F Eivazi. 2007. Environmental risk assessment of phosphate-based remedial technology in metal contaminated urban and mining areas in a selected Missouri Superfund site. US EPA final report, grant number R831071. http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/6267/report/F Accessed August 12, 2011.